Achieving Ultra Low EVM through Signal Chain Optimization

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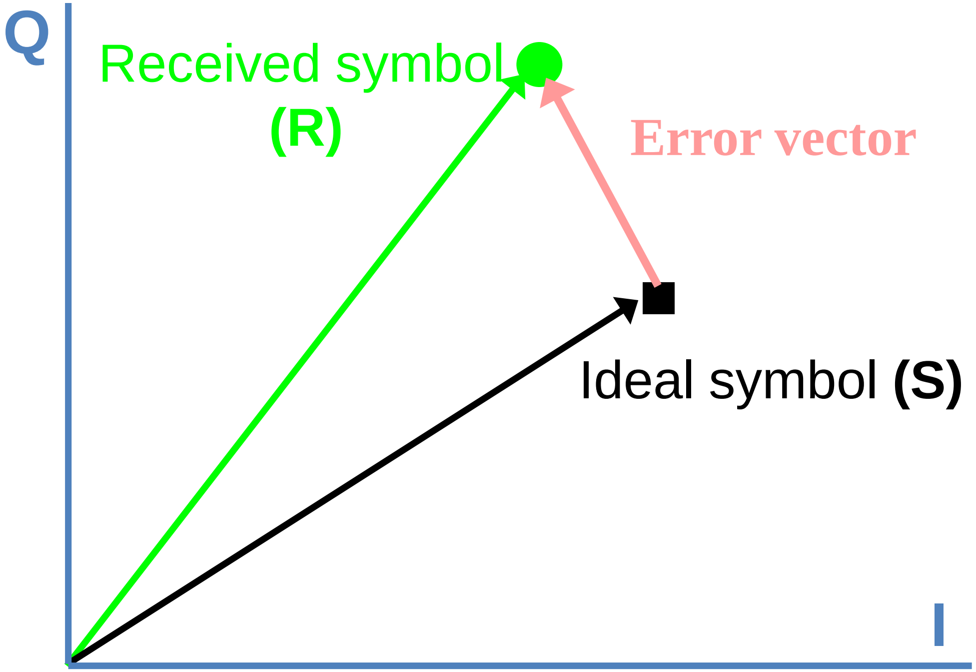
Motivation

- Error Vector Magnitude (EVM) is an useful performance indicator for RF systems
- Instruments that measure EVM need to perform much better than the device under test
- Several design approaches can be followed to achieve ultra low EVM in the signal chains

Outline

- Definition of EVM
- Major sources of degradation
- Signal Chain Optimization

Error Vector Magnitude (EVM)

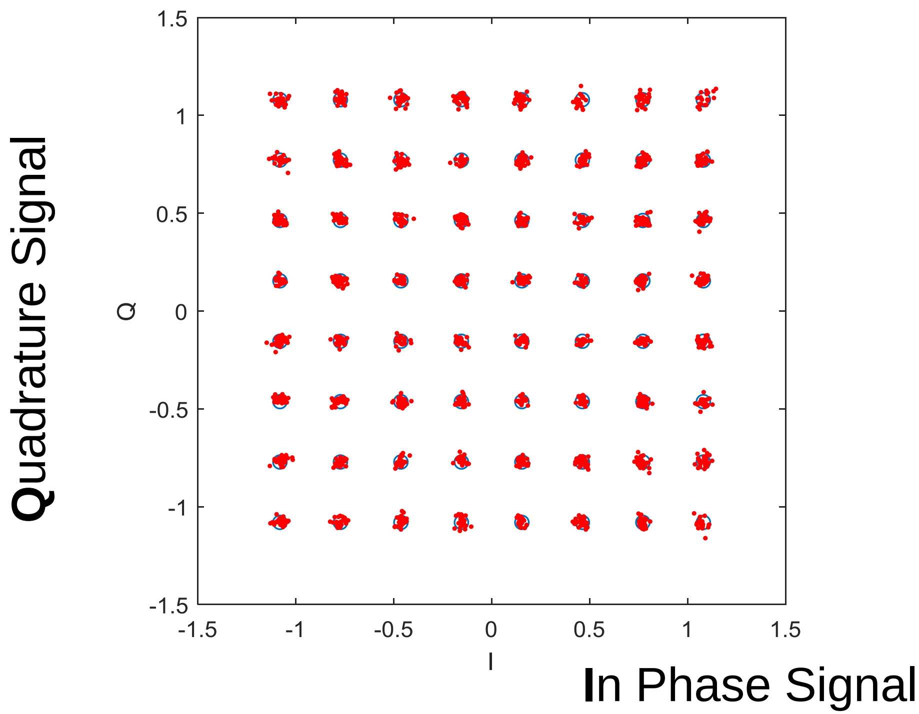


- RMS value for Error Vector Magnitude is specified in communication standards
- -35dB for IEEE 802.11AC MCS9

$$EVM_{frame} = \sqrt{\frac{\sum_{j=1}^{Lp}\sum_{i=1}^{N_C}(R_{i,j} - S_{i,j})^2}{N_C x L_p x P_0}}$$

L_p=Length of the packet
N_c=Number of sub-carriers
P_0=average power

Constellation Diagram



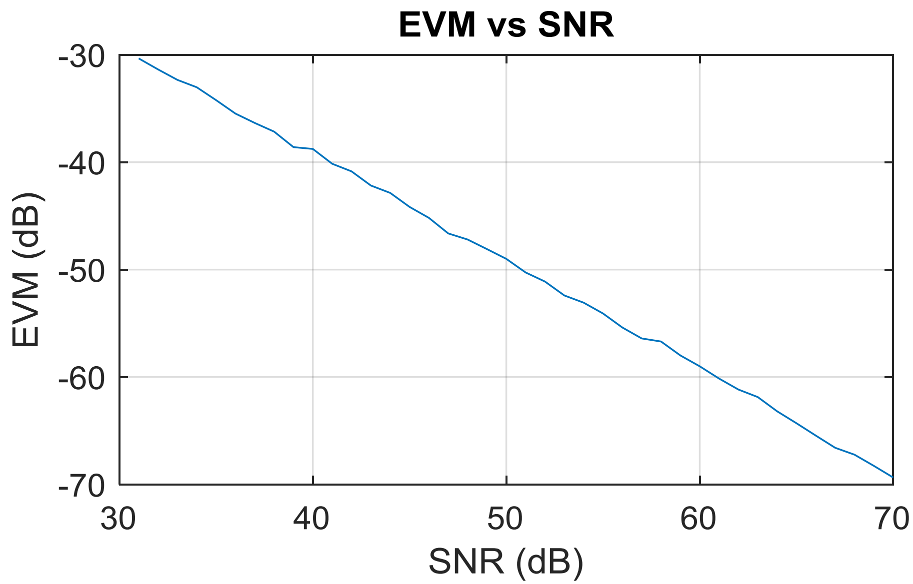
- Signals are represented in constellation diagrams for EVM analysis
- Each constellation point is constructed using In phase (I) and quadrature components (Q)

Factors that Impact EVM

- Any and all factors that alter the quality of the signal will result in poor EVM
- Major factors
  - Noise & Signal to Noise Ratio
  - Non-linear distortion
  - Phase Noise
  - Sampling clock errors

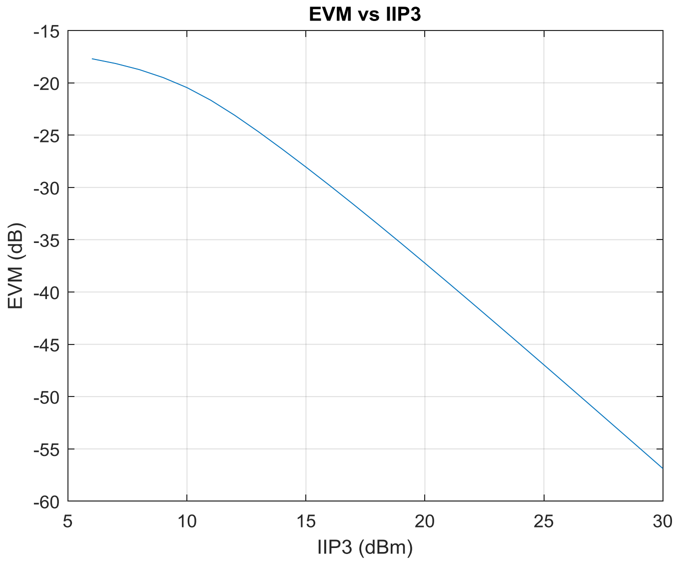
Noise & SNR

- Signal to noise ratio directly impacts the EVM
- Adopt design practices that minimizes the noise figure of the signal chain

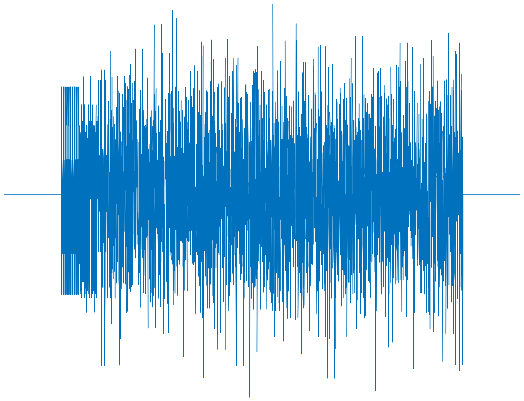


Waveform: 20MHz wide IEEE802.11A signal

Non-linear Distortion



Signal: IEEE 802.11A waveform at 0dBm RF power

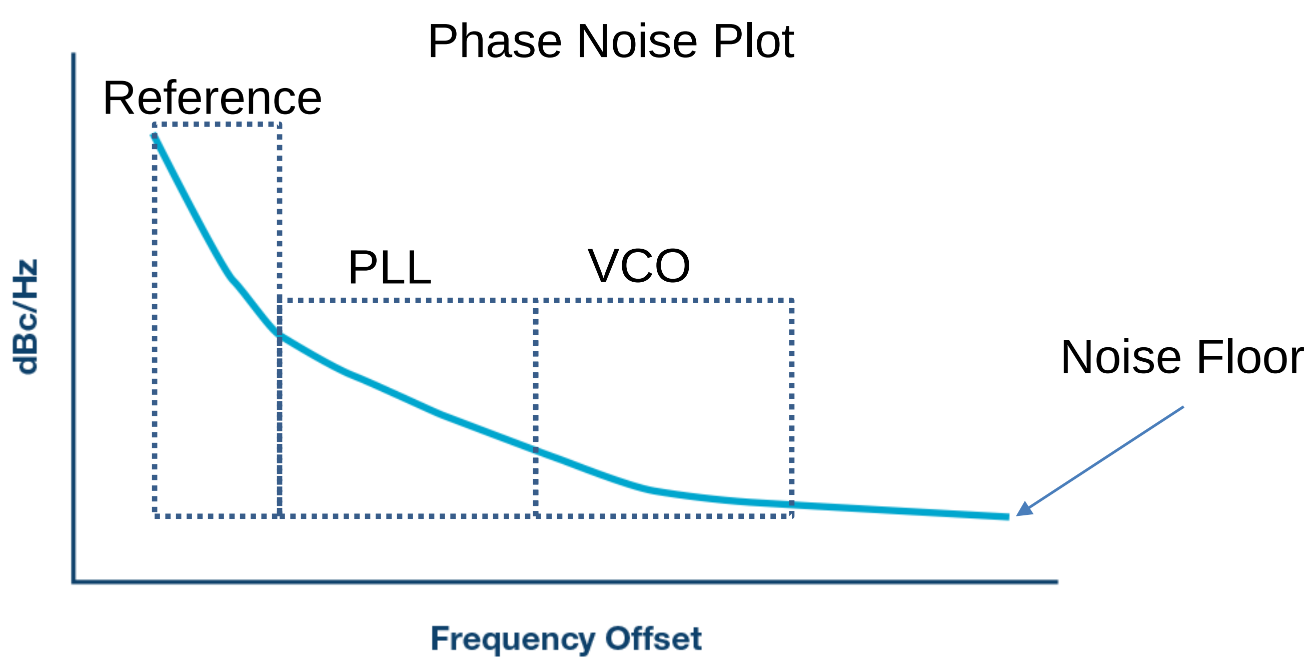


IEEE 802.11A waveform, Peak to average power ratio:9dB

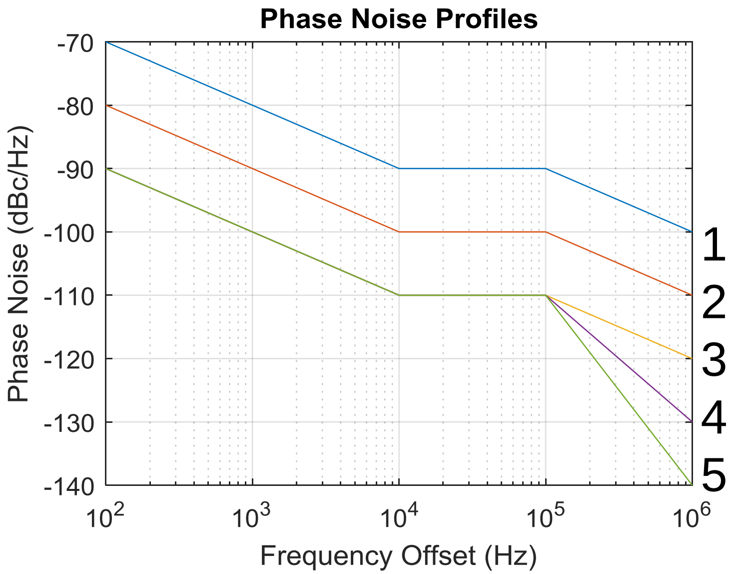
- Non-linear distortion products may fall within the bandwidth of the signal
  - More degradation with multi-carrier modulation schemes, such as OFDM
- Ensure that the signal is well within the linear operating region of the system
  - For example, a 0dBM OFDM modulated signal can have a peak power of +9dBm, the system should have a P1dB point above this power level to ensure the signal is not distorted
  - Calculate the minimum IIP_3 as follows:
    - Average Power + Peak to Average Power Ratio + 9.6dB +5dB = IIP_3 (+9.6dB → P1dB to IIP3 difference, 5dB → Margin for signal peak to P1dB)

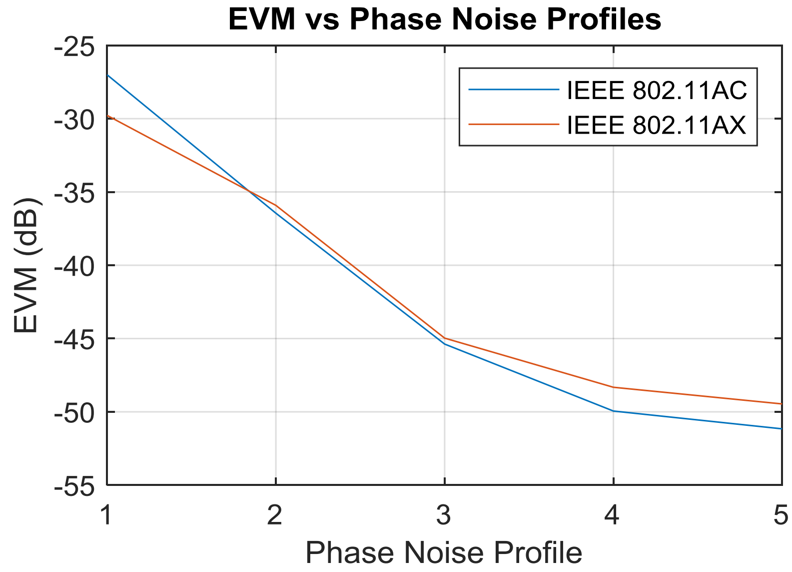
Phase Noise

- Phase noise is caused by random changes in the output frequency of oscillators
  - reference drifts, VCO drift, jitter
- Phase noise degrades the spectral purity of modulated signals



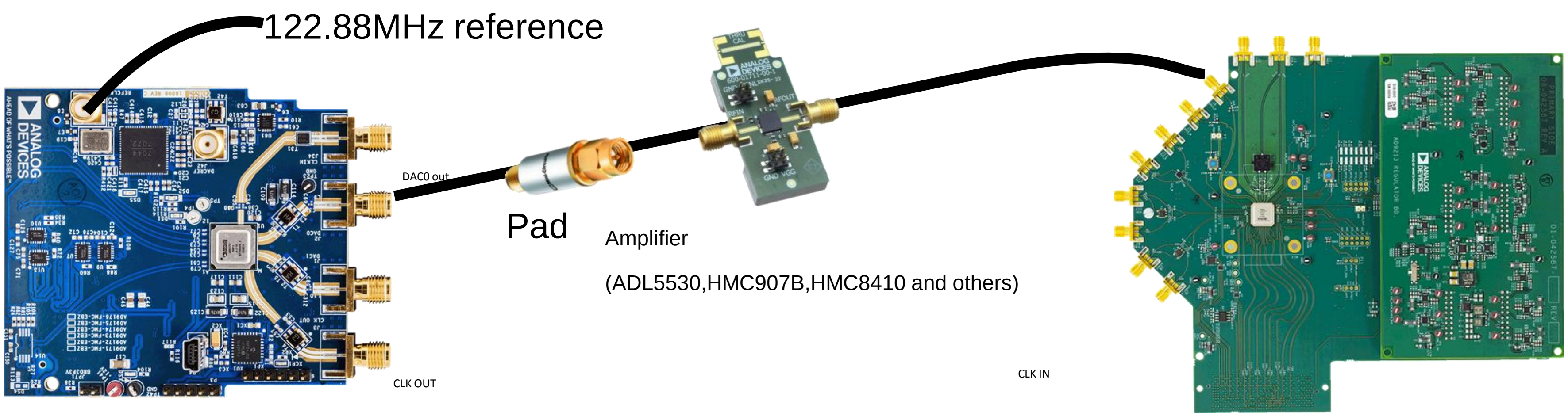
Phase Noise Impact on EVM





- Higher levels of phase noise degrades EVM
  - EVM data are collected through measurements on bench instruments
- Sub-carrier spacing may cause more sensitivity in some areas
  - IEEE 802.11AX sub-carrier spacing is 78.125kHz → Sensitive to close in phase noise
  - IEEE 802.11AC sub-carrier spacing is 312.5kHz → Sensitive to higher phase noise offsets

EVM Experiment Setup

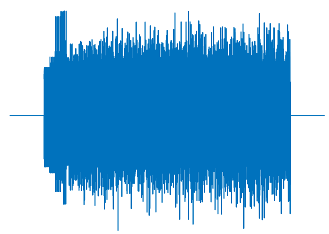


AD9172-FMC-EBZ

- JESD Mode 8, 8x interpolation
- 1.2288e9 GHz data rate
- 9.8304GHz clock rate

AD9213-10GEBZ

- Full data rate
- 9.8304GHz clock rate

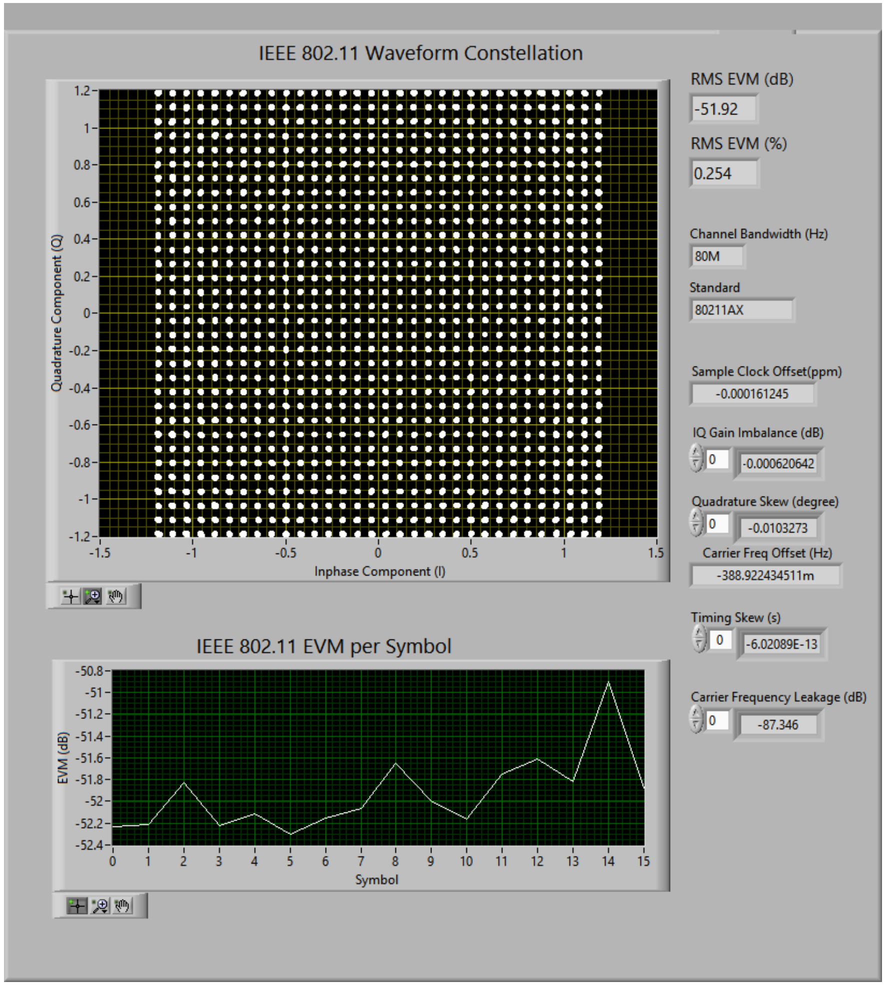


Waveform: IEEE802.11AX, MCS10, SU

PAPR:12.63

EVM of an Non-Optimum System

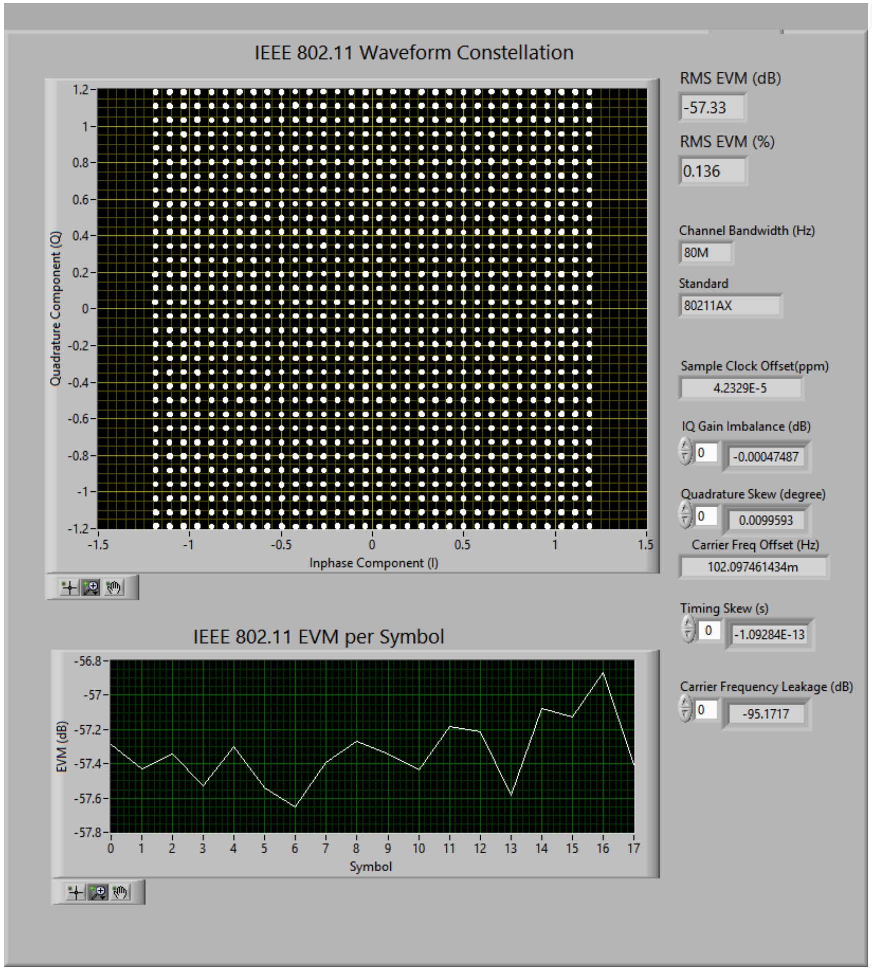
EVM: -52dB



- A noisy & non-linear driver amplifier is used to obtain the EVM at 2GHz

EVM of an Optimized System

EVM: -57dB



- An amplifier with a higher OIP3 and lower noise figure is selected
- The sample rate of the system is increased by 50%
- Results in 5dB EVM improvement

Summary

- EVM is a very useful performance parameter for RF systems
- Signal chains can be optimized to obtain the best EVM performance
- Major contributors to EVM are
  - Non-linearity
  - Noise
  - Phase Noise